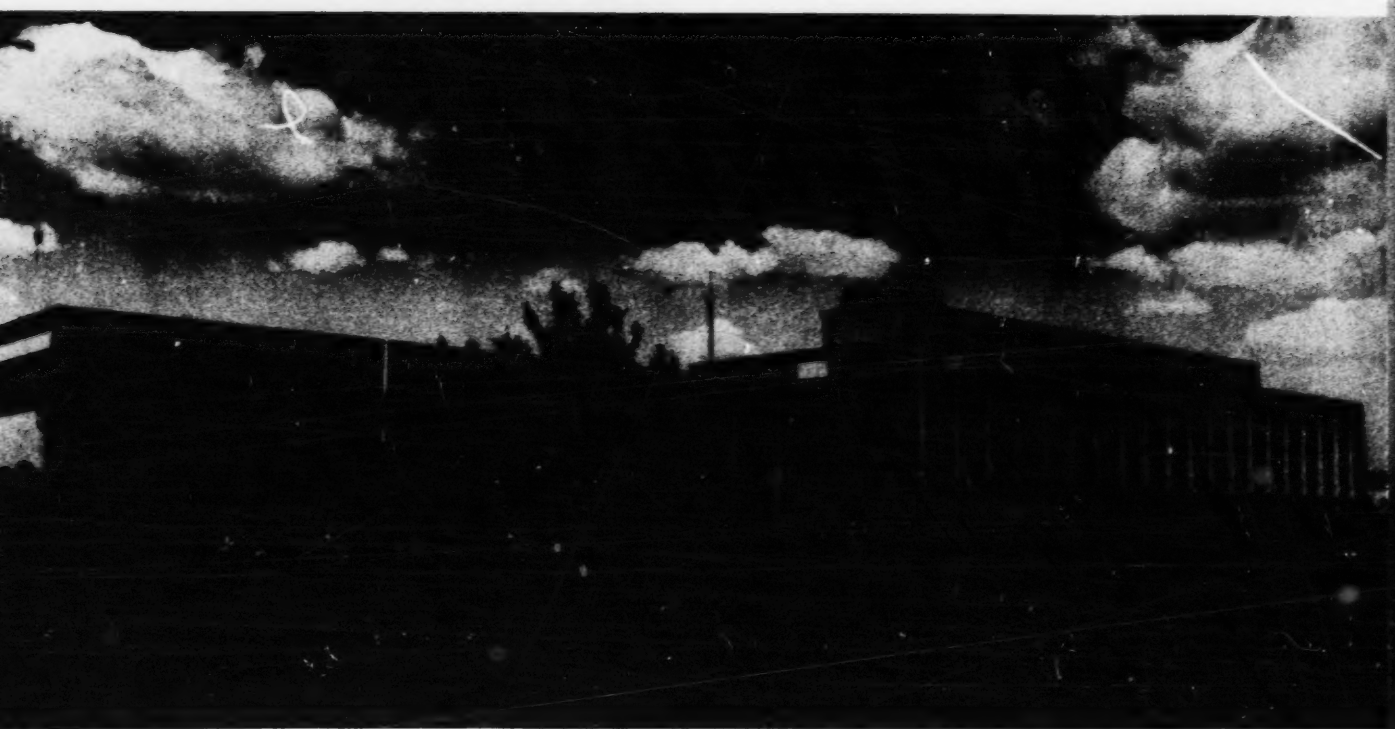
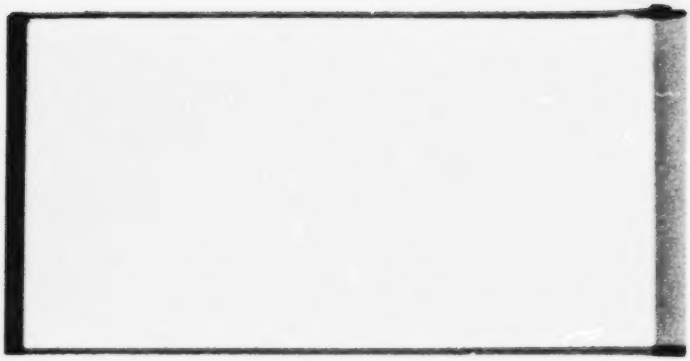
ontario hydro
research division





Named in honour of Dr. W.P. Dobson, the Research Division's director from 1914 to 1953, the building shown on the front cover was first occupied in 1961. Along with the adjacent pump testing complex and the high-voltage, high-current and radioactive materials laboratories, it accommodates much of the research, development and testing work performed in support of the diverse technical needs of Ontario Hydro.

The Research Division's staff is engaged on a wide range of problems relating to the design, construction, operation and maintenance of the power system and to the efficient, economical use of electric power.

Ontario Hydro, Research Division
800 Kipling Avenue,
Toronto, Ontario, Canada
M8Z 5S4

Telex: 06-984-525-706

Phone: (416)231-4111

91602
new 82-10

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if
Reproduced in Whole or in Part.

ontario hydro
research division

LARVAL FISH SAMPLING METHODS FOR SMALL INLAND LAKES - A LITERATURE REVIEW

Report No 83-136-K

W.E. Carey
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

Literature on methods of sampling larval fish in small inland lakes was reviewed with particular emphasis on four fish species: yellow perch *(Perca flavescens)*, yellow pickerel *(Stizostedion vitreum)*, cisco *(Coregonus artedii)* and northern pike *(Esox lucius)*. The review was performed with the intent of providing information directly relevant to fish studies conducted at Atikokan GS. Variable early life history distribution patterns among the selected fish larvae indicated that several sampling methods would be required and that a functional separation of sampling techniques into inshore and offshore methods was possible. Methods considered most appropriate for inshore sampling are short fine mesh beach seines and illuminated Breder traps. Push-net sampling appears to be the most effective offshore larval fish sampling method.

job	file	date	report no.
740634-590-092	837.311	April 15, 1983	83-136-K

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
2.0 LIFE HISTORY DATA	2
2.1 Yellow Perch	2
2.2 Yellow Pickerel	3
2.3 Northern Pike	3
2.4 Cisco	3
2.5 Summary of Early Life History Data	4
3.0 EVALUATION OF LARVAL FISH SAMPLING METHODS	4
3.1 Inshore Methods	6
3.1.1 Push-Nets	6
3.1.2 Portable Pumps	8
3.1.3 Drop Nets and Lift Nets	9
3.1.4 Beach Seines	9
3.1.5 Minnow Traps and Breder Traps	10
3.2 Offshore Methods	10
3.2.1 Channel Net	10
3.2.2 Push-Nets	11
3.2.3 Conical Plankton Tow Nets	13
3.2.4 High-Speed Plankton Nets	14
3.2.5 Purse Seines	16
4.0 SUMMARY AND CONCLUSIONS	16
ACKNOWLEDGEMENTS	18
REFERENCES	19
DISTRIBUTION	last page

91601
new 82-10

ontario hydro
research division

To Mr. F.J. Kee
Director of Research

LARVAL FISH SAMPLING METHODS FOR SMALL INLAND LAKES - A LITERATURE REVIEW

1.0 INTRODUCTION

The establishment of a cooling water circuit at the proposed Atikokan Generating Station near Atikokan, Ontario will introduce additional heat to and increase current activity in the existing watershed. Assessment of generating station impact on larval fish species composition and abundance is an integral part of fish population monitoring in the affected lake system, and requires deployment of effective collecting gear for each target species.

This report reviews a variety of larval fish sampling techniques and assesses their applicability to small inland lake situations. Information derived from this review is expected to contribute substantially to the fish montitoring program in Snow Lake, the first lake in the proposed cooling lake circuit.

In order to facilitate experimental work planned for Snow Lake, sampling techniques for the larvae of the following fish species are emphasized: yellow perch *(Perca flavescens)*, northern pike *(Esox lucius)*, cisco *(Coregonus artedii)* and yellow pickerel *(Stizostedion vitreum)*. Specific information is presented on the adult spawning behaviour and the horizontal and vertical distribution patterns of the larvae of the selected fish species. This approach allows for evaluation of larval fish sampling methods based on a knowledge of early life history features, recognizing that sampling gear and strategies may differ according to the lake zone inhabited by larval fish during early developmental phases.

Detailed descriptions of sampling gears are not provided in this review since these are available from the literature (eg Fraser, 1968, Ontario Hydro Research Division Report No 80-186-K;

Bagenal and Nellen, 1980). Larval fish sampling procedures are evaluated in terms of several criteria including handling, portability, filtration performance, collection efficiency, and operational and maintenance costs.

2.0 LIFE HISTORY DATA

It is well-known that the newly-hatched larvae of many freshwater fish species inhabit small bays and back-waters along the edges of lakes during the spring. Thus sampling for most newly-hatched freshwater fish larvae must be conducted in very shallow water, often in the vicinity of submergent vegetation. Although most fresh water fish larvae originate in the littoral zone, older larvae of some fish species commonly occur in the open surface waters of the epilimnetic zone (Bagenal and Nellen, 1980). Consequently the distribution of fish larvae during early and late developmental phases is important in relation to the type of collecting gear used. The fish species for which salient life history parameters will be described ie yellow pickerel, cisco, northern pike and yellow perch, occur in many of the small lakes in the Atikokan district (Acres, 1976; Johnson et al, 1977). Different temporal distribution patterns are demonstrated by the larvae of the above fish species, a factor which compounds the sampling problem when two or more of these species occur in the same lake.

2.1 Yellow Perch

Yellow perch spawn during the spring between mid-April and early May in shallow protected lake areas where rooted vegetation occurs. Spawning takes place at night when the water temperature ranges between 8.9°C and 11.2°C (Scott and Crossman, 1973). The semi-buoyant egg masses released during spawning are adhesive and become attached to submerged vegetation or are lost due to wave and current action. Hatching is temperature-dependent and egg incubation can last 8-27 days (Scott and Crossman, 1973).

Newly-hatched yellow perch larvae are about 5.0-6.0 mm in length, photopositive and transparent. These young fish remain in shallow vegetated areas for approximately 5 days after hatching. By late spring and early summer the larvae are found in the top 2 m of the epilimnetic zone, a consequence of passive drifting with surface currents (Houde, 1969). The majority of larval perch migrate inshore and become demersal during midsummer when they are about 25 mm long (Forney, 1971; Wong and Ward, 1972). A similar larval distribution pattern has been observed for the Eurasian perch, *Perca fluviatilis* (Coles, 1981).

2.2 Yellow Pickerel

According to Scott and Crossman (1973) yellow pickerel spawn between early April and late May (depending on latitude) shortly after ice break-up. Spawning occurs at night in shallow rocky areas of tributary rivers, or below dams or falls, suggesting a requirement for current. However, spawning may also occur over the gravel shoals of lakes. Eggs are broadcast over the spawning area and settle into rock crevices where they remain for 12-18 days. Upon hatching the young are photopositive, 6.0-8.0 mm long and transparent (Scott and Crossman, 1973).

The newly-hatched yellow pickerel larvae have poor swimming ability and are swept rapidly from riverine or lacustrine spawning locations into the upper levels of the epilimnion, where they are associated with yellow perch larvae at 1-3 m depth (Houde, 1969). Wind-generated surface currents can apparently concentrate the yellow pickerel larvae in protected bays, although they are still limnetic. Houde (1969) found that in Oneida Lake, New York, yellow pickerel larvae were retained in a bay by an eddy current, and subsequently occupied areas of lowest current velocity within the bay. Yellow pickerel larvae alter depth distribution in response to surface currents, shifting from 2 m to 3 m during strong surface current activity (Houde, 1969). A transition to a demersal existence occurs when the larvae reach 25-30 mm total length (Houde and Forney, 1970).

2.3 Northern Pike

Northern pike spawn at water temperatures of 4.4°-11.1°C immediately after the ice melts in early April to early May (Scott and Crossman, 1973). The typical spawning habitat is a shallow, heavily-vegetated area of a river or lake bay. Spawning occurs during the day and the fertilized eggs adhere to vegetation as they settle to the bottom. The normal incubation period is 12-14 days. After hatching, the young larvae are about 6.0-8.0 mm long and are inactive, remaining attached to submergent vegetation for a period of 6-10 days. The larvae stay in the vicinity of the shallow spawning area for 3-4 weeks and subsequently move about within the littoral zone, never venturing into open water (Franklin and Smith, 1963; Scott and Crossman, 1973).

2.4 Cisco

The spawning period for the cisco is in the fall during declining water temperatures (3.0-5.0°C). Cisco spawn in shallow water, usually over a gravel or stony substrate (Scott and Crossman, 1973). Eggs are deposited on the bottom and develop over the winter, the entire incubation period lasting 92-106 days, depending on time of spawning and spring water temperatures.

Newly-hatched cisco larvae are about 8.5-10.0 mm in length (Pritchard, 1930, Fish, 1932) and photopositive (John and Hasler, 1956). The larvae initially remain inshore in very shallow, protected areas, often amongst reeds (Pritchard, 1930). By late spring and early summer cisco larvae have moved offshore, occupying the surface waters of the epilimnion, particularly over the deepest lake sites (Clady, 1976a). Older cisco larvae probably disperse into deeper epilimnetic strata by early summer, since they are not captured inshore or in offshore surface waters at that time (Clady, 1976a).

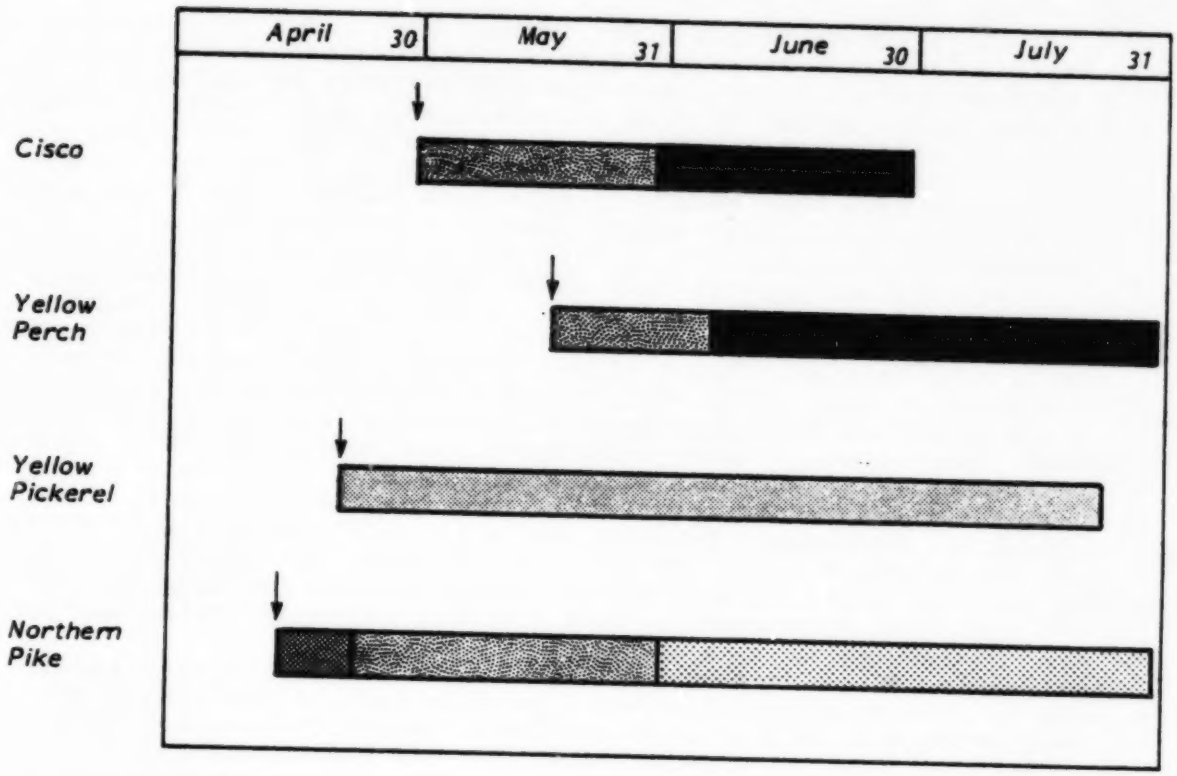
2.5 Summary of Early Life History Data

It is evident that freshwater fish larvae occupy many different habitats within a lacustrine environment. Sampling programs designed to capture several larval fish species will require comparative spatial and temporal distribution data as shown in Figure 1 for the four selected fish species. Simultaneous capture of cisco, yellow perch and yellow pickerel larvae should be possible in June by sampling the upper 3 m of epilimnetic water (Figure 1). However, more intensive sampling in surface waters of lake bays for yellow pickerel larvae may be required (Houde, 1969). Inshore sampling in and adjacent to vegetation beds during the spring may produce different larval fish species. For example newly-hatched northern pike, cisco and yellow perch larvae may appear in sequence in shallow, weedy bays during the spring (Figure 1).

Although substantial overlap in the temporal distribution of cisco and northern pike larvae occurs during May, different sampling gears may be necessary since pike larvae, are larger and occupy heavily vegetated areas (Franklin and Smith, 1963). Further, a unique sampling method may be required to catch older pike larvae, which, unlike the other fish larvae examined, do not pass through a limnetic phase (Figure 1). Catchability of cisco, yellow perch and yellow pickerel larvae declines rapidly in the summer and may be indicative of the transformation to juveniles, corresponding to movement to deeper strata.

3.0 EVALUATION OF LARVAL FISH SAMPLING METHODS

For the purposes of this review, two broad categories of larval fish sampling techniques are identified. One group of methods includes devices capable of sampling for very young larvae in shallow (<1 m deep) water either over or through rooted vegetation. The second class of sampling methods contains those types of gear which are deployed in open, surface epilimnetic waters to capture older larvae.



Legend

- *Close inshore, attached to aquatic macrophytes (dense beds)*
- *Close inshore, near aquatic vegetation of shallow protected areas*
- *Offshore, in surface waters (1-2 m) of epilimnion*
- *Offshore, in 2-3 m of eplimnetic water*
- *Inshore, between 1-5 m depth near aquatic vegetation*
- *Approximate time of hatching*

FIGURE 1

SPATIAL AND TEMPORAL DISTRIBUTION PATTERN OF CISCO, YELLOW PERCH, YELLOW PICKEREL, AND NORTHERN PIKE LARVAE

3.1 Inshore Methods

3.1.1 Push-Nets

Shallow water areas require samplers designed specially for nearshore manoeuverability. Several types of push-net samplers have been tested with variable success. Herke (1969) designed a surface trawl which consisted of a pair of tarred nylon nets 5 m in length attached to a 4.2 m x 1.2 m rectangular aluminum frame. The trawl could be operated at variable depths between 0.3 and 1.2 m, and was most effective when used with an air-boat. During sampling the mouth of the trawl is pulled down into sampling position as the boat is accelerated; the buoyant aluminum frame rises to the water surface when the boat is stopped. Although the trawl can be used in vegetated areas it is cumbersome to handle and more expensive than other push-nets (Herke, 1969). Gale and Mohr (1978) found that push-nets with enlarged posterior portions were difficult to wash in the field but were effective in preventing back pressures in the nets. Their push-net system functioned well in water less than 1 m deep and was used with an inexpensive aluminum 'V'-bottomed boat. However, Gale and Mohr (1978) recommended the installation of a flexion joint to allow backward tipping of the frame if large rocks were encounterd. The major advantage of this type of push-net apparatus was the ability to raise the nets out of the water, thus facilitating greater nearshore handling.

Miller (1973) designed a push-net system which could be operated from a twin-hulled boat such as a catamaran (Figure 2a). A system of forwardly-directed steel cables attached to a galvanized pipe frame controlled the net mouth orientation of a pair of standard bongo nets. Shallow water sampling was easily conducted and samples were retrieved through a well in the boat. The principal advantage of this method was that contiguous samples could be collected, allowing the detection of fine-scale variations in abundance of larval fish. However, manoeuverability may be restricted in very shallow inshore waters since the boat length would effectively increase when nets are in sampling position (Figure 2a). Holland and Libey (1981) suggested that a sliding vertical aluminum frame mounted on the bow of a small boat would provide sufficient support for conical net attachment. This assembly could facilitate sampling as close as 0.25 m (in depth) from the shore.

A portable push-net apparatus described by Tarplee et al (1979) provided adequate manoeuverability in restricted areas and was operated from a 4.5 m boat. The system consisted of a pair of half-metre conical tow nets positioned on either side of a boat by means of vertical net-bars attached to a horizontal main beam (Figure 2b). Sampling depth was adjustable and the nets could

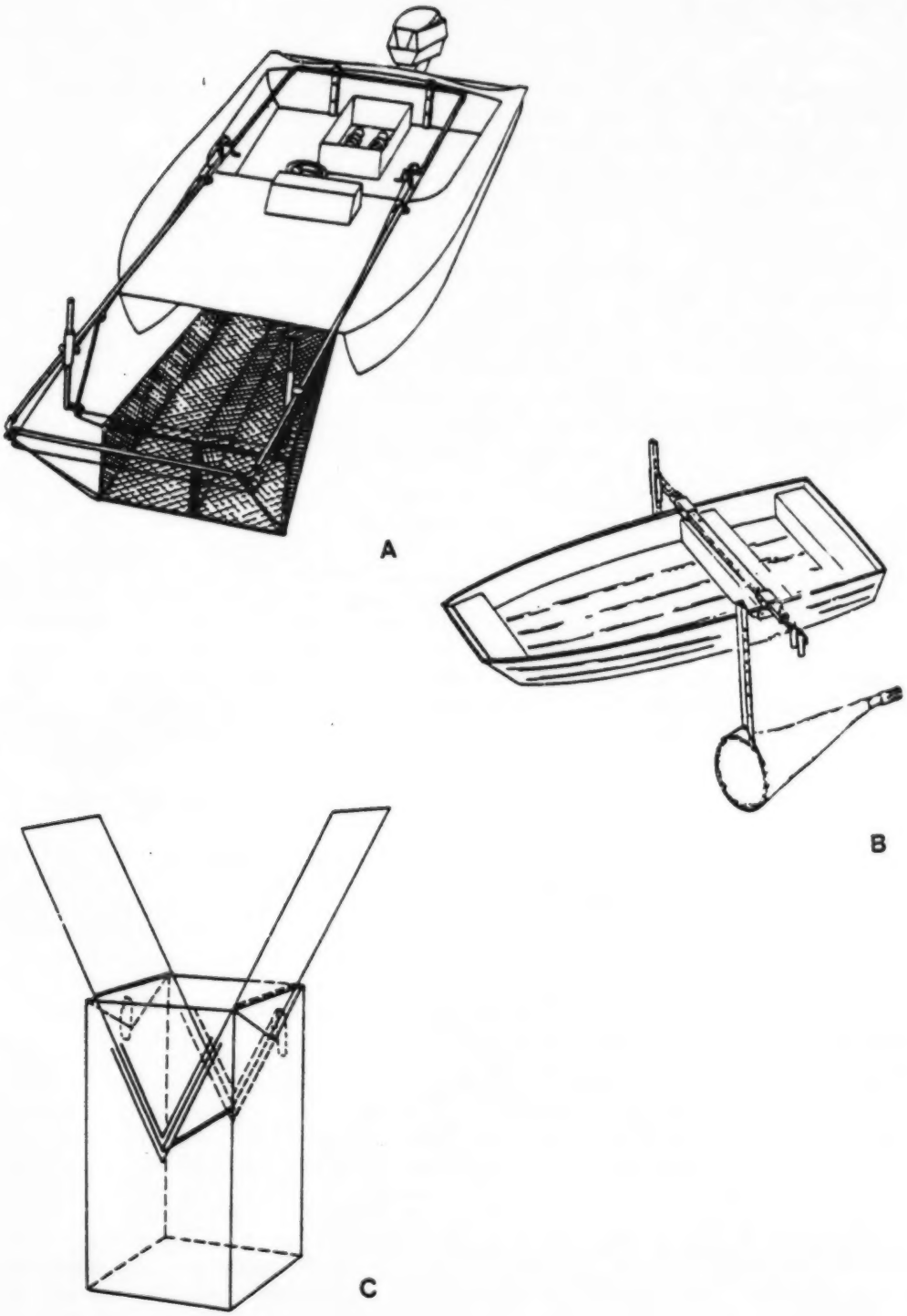


FIGURE 2
SPECIAL TYPES OF LARVAL FISH SAMPLING GEAR
(A) FRONT-MOUNTED PUSH-NET (AFTER MILLER, 1973)
(B) SIDE-MOUNTED PUSH-NET (AFTER TARPLEE ET AL., 1979)
(C) BREDER TRAP (AFTER BREDER, 1960)

161100 RD

be pivoted into sampling position just outside of the wake of the boat. Since the ring of the tow net was welded to the vertical net-bar, the entire assembly must be removed if a larger diameter tow net is required. The authors reported that 180° turns could easily be made, thus enabling narrow channels to be sampled.

All of the above push-net sampling methods are quantitative if current meters are used to measure the volume of water sampled. However, net clogging as a consequence of the use of fine gauze (a requirement for newly-hatched fish larvae) may decrease the filtration efficiency of the plankton nets (Tranter and Smith, 1968). Net clogging by detached vegetation or other littoral debris may further reduce filtration efficiency (Lam, 1977) resulting in an extremely low volume of water being sampled.

A general problem associated with push-net sampling in shallow littoral locations is the fouling of engine propellers and cooling systems by aquatic macrophytes, debris and mud. Therefore push-net sampling close to the lake shoreline will be restricted by the depth of water available for safe boat passage. This factor will also influence the velocity at which nets can be pushed through the water. Low velocities may not seriously affect the catchability of small newly-hatched larvae such as those of yellow perch, but may result in reduced catches of the large newly-hatched larvae of pike and cisco due to net avoidance.

3.1.2 Portable Pumps

A number of researchers have reported that portable pumps may be preferable to fixed plankton nets in deriving larval fish entrainment estimates at power plant cooling water intakes (Leithiser et al, 1979; Cada and Loar, 1982). The advantges of sampling with a portable pump are a) relative ease of operation b) the elimination of current meter problems and c) the easy regulation of sampling volume by altering pumping duration (Gale and Mohr, 1978). In the vegetated areas of the littoral zone, a low-volume pump would be required in order to reduce the clogging of pump intakes and catchment screens (Cada and Loar, 1982), although some clogging may still occur (Stevens, 1977). Pumps are relatively expensive, and even low-volume portable pumps can cost up to $6,000 (Ontario Hydro Research Division Report No 80-186-K).

A major drawback to the use of low-volume pumps in inshore situations is that fish larvae present in low densities may be missed, unless pumping is continued for a long period of time. Whereas a 0.5 m net towed at a velocity of 1 m/s for 15 minutes will sample approximately 180 m^3 of water (Ontario Hydro

Research Division Report No 80-186-K), a low-volume pump (fitted with a 7.6 cm diameter intake hose and a cylindrical trash screen with 6.5 cm^2 square openings) will sample only 16.7 m^3 of water in the same time period at an intake velocity of about 1.1 m/s (Cada and Loar, 1982). The pump has to be operated continuously for over 2.5 h under the same conditions to sample a volume of water equivalent to the amount sampled by the towed net. This requirement makes the pump a rather impractical larval fish sampling method.

3.1.3 Drop Nets and Lift Nets

There are several non-quantitative or semi-quantitative sampling techniques which have been used to capture juvenile fish in shallow water situations including drop and lift nets (Kushlan, 1974), seines (Derickson and Price, 1973) and emergent traps (Stauffer, 1981). Some of these techniques can be modified to sample larval fish by incorporating smaller mesh sizes, however several disadvantages still remain.

Drop nets and lift nets take instantaneous samples but usually sample a relatively small area (<30 m^2)(Kjelson, 1977). These devices normally have limited portability or else require a substantial amount of effort to obtain replicate samples. In addition, drop nets and lift nets do not concentrate fish in one area (an advantage when larval fish densities are low), may frighten fish unless operated from a remote location, and often require tedious laboratory separation of fish from mud and debris (Kushlan, 1974).

3.1.4 Beach Seines

Coles (1981) used a 3 mm mesh beach seine, 36.5 m long by 4.8 m deep, to sample larval perch *(Perca fluviatilis)* in inshore lake areas, but concluded that the dense growth of macrophytes present limited the sampling success of the method. Campana (1982) recommended the use of short (<9 m) pole seines for sampling through dense aquatic vegetation. He suggested that conversion of a two-man beach seine for use by a single person could be accomplished by attaching a wooden beam to the distal ends of the seine and tying a length of polypropylene line with a pulling handle to the centre of the beam. The modified seine is both portable and easily assembled, and can be operated by a single individual of average strength (Campana, 1982). Although seines do not provide estimates of absolute fish density, standard seine hauls are useful for deriving estimates of relative fish abundance, as well as determining larval fish nursery areas (Coles, 1981). A fine mesh (<1 mm) beach seine will increase the sampling time necessary due to greater debris accumulation, with the result that sorting of samples becomes a more laborious

Research Division Report No 80-186-K), a low-volume pump (fitted with a 7.6 cm diameter intake hose and a cylindrical trash screen with 6.5 cm^2 square openings) will sample only 16.7 m^3 of water in the same time period at an intake velocity of about 1.1 m/s (Cada and Loar, 1982). The pump has to be operated continuously for over 2.5 h under the same conditions to sample a volume of water equivalent to the amount sampled by the towed net. This requirement makes the pump a rather impractical larval fish sampling method.

3.1.3 Drop Nets and Lift Nets

There are several non-quantitative or semi-quantitative sampling techniques which have been used to capture juvenile fish in shallow water situations including drop and lift nets (Kushlan, 1974), seines (Derickson and Price, 1973) and emergent traps (Stauffer, 1981). Some of these techniques can be modified to sample larval fish by incorporating smaller mesh sizes, however several disadvantages still remain.

Drop nets and lift nets take instantaneous samples but usually sample a relatively small area (<30 m^2)(Kjelson, 1977). These devices normally have limited portability or else require a substantial amount of effort to obtain replicate samples. In addition, drop nets and lift nets do not concentrate fish in one area (an advantage when larval fish densities are low), may frighten fish unless operated from a remote location, and often require tedious laboratory separation of fish from mud and debris (Kushlan, 1974).

3.1.4 Beach Seines

Coles (1981) used a 3 mm mesh beach seine, 36.5 m long by 4.8 m deep, to sample larval perch *(Perca fluviatilis)* in inshore lake areas, but concluded that the dense growth of macrophytes present limited the sampling success of the method. Campana (1982) recommended the use of short (<9 m) pole seines for sampling through dense aquatic vegetation. He suggested that conversion of a two-man beach seine for use by a single person could be accomplished by attaching a wooden beam to the distal ends of the seine and tying a length of polypropylene line with a pulling handle to the centre of the beam. The modified seine is both portable and easily assembled, and can be operated by a single individual of average strength (Campana, 1982). Although seines do not provide estimates of absolute fish density, standard seine hauls are useful for deriving estimates of relative fish abundance, as well as determining larval fish nursery areas (Coles, 1981). A fine mesh (<1 mm) beach seine will increase the sampling time necessary due to greater debris accumulation, with the result that sorting of samples becomes a more laborious

process. Beach seines are less expensive than pumps or push-net systems (approx $500).

3.1.5 Minnow Traps and Breder Traps

Minnow traps and Breder traps (Breder, 1960) may provide qualitative information on inshore distribution and species composition of larval fish populations. Weighted plastic minnow traps with double entry funnels and lined with 1 mm mesh fibreglass window screen were successfully used to capture lake trout *(Salvelinus namaycush)* fry (Stauffer, 1981). Several minnow traps, lined with very small mesh screening, would be required to sample yellow perch or pike larvae in vegetated inshore areas, unless the larvae were abundant. Wind-generated surface currents may be important in transporting newly-hatched fish larvae into minnow traps since no active concentrating mechanism exists for this gear.

The Breder trap is a very effective larval fish trap constructed from pieces of clear plastic (Nellen and Schnack, 1975). The trap consists of a box with removable wings which funnel inwards to form a narrow aperture, which can be adjusted to catch various sizes of fish larvae (Figure 2c). It is an ideal device for collecting fish larvae in areas of dense vegetation and showed an increase in catching efficiency when used at night with the aperture illuminated from below (Coles, 1981). Thus the positive photoresponse of yellow perch and cisco larvae may render these species highly susceptible to Breder traps set with an internal light source. The apparatus can be constructed at low cost, is portable, and easy to operate.

3.2 Offshore Methods

A wide variety of sampling gear may be used to capture epilimnetic fish larvae. In general these techniques are based on the principle of active filtration of fish larvae from a measured column of water with a plankton net. A major difference between methods is the way in which the concentrating device (net) interacts with the water. The interaction process is a function of several factors including mesh size, net speed, net configuration and the open area/mouth area ratio of the net (Tranter and Smith, 1968). The main categories of open water larval fish sampling techniques are push-net systems, conical tow net systems and high-speed plankton samplers.

3.2.1 Channel Net

A special type of gear which may be used to catch larval fish in narrow channels (eg at lake outlets) is the channel net developed by Lewis et al (1970). The net consisted of a 0.5 mm nylon

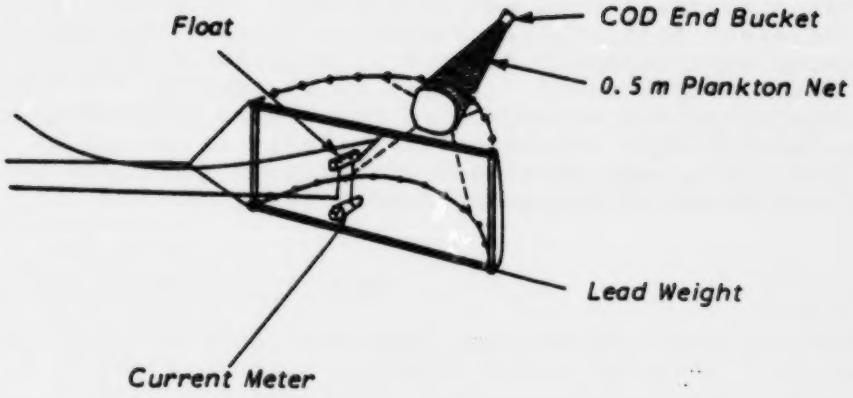
mesh 0.5 m diameter plankton net to which four pieces of 3 mm square nylon webbing were attached to form two wings (Figure 3). Float and lead lines were attached to the top and bottom of the wings, respectively. A 1 m x 3 m metal frame held the ends of the wings apart. The net, which was dyed green to reduce visibility, could be fished at any position between the surface to the bottom of the channel. A current meter suspended by floats near the centre of the mouth of the net provided an estimate of the volume of water sampled (Figure 3).

The advantages of the channel net are that it (i) requires minimal handling when set in a fixed location (ii) can provide quantitative samples and (iii) probably filters a greater volume of water than an unmodified plankton net. The extent of clogging by floating debris is not known. This sampling method may work well in small channels connecting two lake basins, facilitating analysis of passive interbasin larval fish movement. Larval fish species such as cisco, yellow perch or yellow pickerel may be susceptible to the channel net during their pelagic phase.

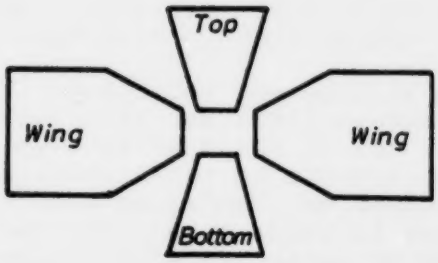
3.2.2 Push-Nets

Push-net sampling systems were described earlier in relation to their manoeuverability in shallow water lacustrine environments. In the open water situation the most important advantages of push-net samplers are (i) the ability to sample outside the boat's wake and (ii) the lack of preceding wires or bridles (Miller, 1973; Nellen and Schnack, 1975). Tow lines and bridles can cause water acceleration and turbulence, providing advanced warning of an oncoming object to fish larvae (Clutter and Anraku, 1968). Push-net devices decrease the potential for net avoidance by fish larvae through the reduction of turbulence ahead of the sampling net.

Amundrud et al (1974) used a bow-mounted push-net system consisting of paired, conical, 61 cm mouth diameter nets supported by a wooden frame to sample perciform larvae in Lake Opinicon, Ontario. Their system was successful in capturing large numbers of fish larvae, including yellow perch larvae 6.0 mm-10.0 mm in total length. The side-mounted push-net apparatus developed by Tarplee et al (1979) demonstrated several advantages over other push-net systems, such as that of Amundrud et al (1974), or Miller (1973). The unit was not only completely portable, but could sample at various depths and was operable from boats of different shapes and sizes (Tarplee et al, 1979). Hodson et al (1981) cautioned that surface push-nets long enough to reach past the stern of a boat could be caught in the propeller. They found that a 1 m plankton net with a 1 to 3 taper (mouth diameter: total length) was adequate for small (5 m long) boats.



(a) Channel Net in Fishing Position



(b) Shape of Separate Sections of Channel Net

FIGURE 3

CHANNEL NET SHOWING (a) NORMAL FISHING POSITION AND
(b) SHAPE OF SEPARATE SECTIONS OF THE NET
(AFTER LEWIS ET AL., 1970)

Few in situ measurements of the filtration efficiency associated with surface push-nets have been reported. Miller (1973) estimated that the decline in filtration efficiency after 30 contiguous samples was only 8.7% for standard bongo nets, while Gale and Mohr (1978) could not detect any substantial differences in current meter readings taken simultaneously inside and outside their surface push-nets. Similarly, the mean filtration efficiency recorded for each of 15 consecutive surface hauls of paired 505 µm mesh Nitex nets (1 m mouth diameter) was consistently around 97% (Hodson et al, 1981). These data suggest that clogging of push-nets should not be a problem during pelagic sampling. Hodson et al (1981) attributed the high filtration efficiencies that they measured to the large open area ratio of the nets (7.7) and the prevention of clogging by spray washing nets after each haul.

3.2.3 Conical Plankton Tow Nets

Conical plankton tow nets have been used extensively in ichthyoplankton entrainment studies (Ontario Hydro Research Division Report Nos 78-192-K and 81-211-K; Bowles and Merriner, 1978) and freshwater larval fish surveys (Houde, 1969; Faber, 1967,1968; Nelson and Walburg, 1977; Ruelle et al, 1977; Nelson, 1980; Cooper et al 1981; Mizera et al, 1981). The most common net sizes used in these studies were 0.5 m and 1.0 m diameter nets, although nets of intermediate sizes have been employed occasionally. Spanovskaya and Grigorash (1977) sampled Eurasian perch *(Perca fluviatilis)* larvae in reservoirs with a 0.6 m diameter, 1 mm mesh conical net. Both yellow perch and yellow pickerel larvae were captured with 0.75 m diameter, 760 µm mesh plankton nets during a limnetic larval fish survey in the Ohio portion of western Lake Erie (Cooper et al, 1981).

The widespread usage of conical tow nets to sample larval fish stems from their relatively low cost, general commercial availability, and their ease of handling in the field. However, there are several disadvantages of conventional tow net sampling. As previously mentioned the towing cable and bridle may cause substantial turbulence ahead of nets. This is a critical point in relation to the sampling of epilimnetic larvae since light levels are usually high enough to facilitate a visual avoidance response which may, in conjunction with responses to change in pressure or other stimuli, serve to carry fish larvae out of the path of a towed net (Clutter and Anraku, 1968). Since large larvae will normally have a greater net avoidance capability than small larvae, tow net sampling may be a size-selective process, underestimating overall larval fish abundance. Conical tow nets can be affected by propwash during deployment and retrieval, with the result that the actual volume of water filtered may exceed the intended sampling volume.

Plankton nets may be towed in a circular pattern at the surface in order to avoid propwash (Cooper et al, 1981). Long conical net tows tend to integrate larval fish from different open water areas, thus destroying fine-scale larval fish distribution patterns.

An initial tow net filtration efficiency of 85% should be achievable if the open area ratio is greater than 3 (Tranter and Smith, 1968). However filtration efficiency characteristically declines as a tow proceeds. Decreasing the taper (mouth diameter: total length) of a conical net should raise its initial filtration efficiency by providing a larger filtration area. An additional advantage of nets with a small taper is that they are partially self-cleaning due to a reduced adherence of fish larvae to the mesh during towing (Faber, 1968).

The Calcofi net, a low-speed net originally developed for marine zooplankton surveys (Ahlstrom, 1954), increases initial filtration efficiency to about 90%. Addition of a cylindrical net portion which precedes the conical net opening serves to enlarge the effective filtration area of the net (Tranter and Smith, 1968). Despite this important feature, the Calcofi net is not suitable for use in small inland lakes since maximum filtration efficiency is achieved by towing the net between two boats (Nellen and Schnack, 1975). A large diameter (mouth area = 1 m^2) Calcofi net has recently been used to catch Eurasian perch *(Perca fluviatilis)* larvae by hauling the net towards an anchored research vessel with a powerful winch (Viljanen and Holopainen, 1982). Large research boats with sufficient winch capacity are generally not available for sampling in small inland lakes.

3.2.4 High-Speed Plankton Nets

High-speed plankton samplers have been shown to reduce the potential for net avoidance by fish larvae (Clutter and Anraku, 1968), and include the Miller, Jet and Gulf III samplers (Bridger, 1958; Miller, 1961; Clarke, 1964). These samplers are characterized by a funnel-shaped cone which reduces the mouth aperture of the net. The presence of a mouth-reducing cone apparently influences the flow of water through the samplers, resulting in an increase in filtration performance (Tranter and Smith, 1968).

In general, constraints on vessel size and the amount of mechanical gear available preclude the routine use of high-speed plankton samplers in small inland lakes. Further, the lake surface area and depth may not be adequate for high-speed tows. For example a single 5 minute tow at 3 m/s with a Miller sampler will cover a distance of about 900 m. It would be impractical

and possibly dangerous to conduct such a tow in lakes where the length is less than 1 km.

The most extensive use of high-speed plankton samplers in inland waters has occurred in 33.6 km long Oneida Lake, New York, where several researchers deployed Miller samplers to capture yellow perch, yellow pickerel and cisco larvae(Houde and Forney, 1970; Noble, 1970, 1972 a,b; Forney, 1975; Clady, 1976 a,b; Hansen and Wahl, 1981). Noble (1970) tested the capture efficiency of the Miller sampler and concluded that: (i) yellow perch and yellow pickerel larvae at least 8 mm long can avoid Miller samplers towed at 3.6 m/s (ii) higher tow velocities (>3.6 m/s) increased the larval fish catches per volume of water filtered (iii) avoidance was a response to a visual stimulus (iv) avoidance could be decreased by immobilizing and disorienting larvae by means of an electric shocker (v) a sampler with an aperture 1.5 times the area of a standard sampler did not appear to be more efficient (vi) higher velocities did not eliminate avoidance by yellow perch larvae and (vii) clear samplers were more efficient at capturing larvae at 0.5 m than at 1.5 m. These results suggest that night sampling with Miller samplers at relatively high towing velocities (5 m/s) may produce large numbers of yellow perch or yellow pickerel larvae. However, this procedure is not recommended for general sampling programs in inland lakes (Noble, 1970).

Additional problems associated with high-speed samplers are the extrusion of small larvae through the mesh during tows (Vannucci, 1968) and damage of fish larvae at higher towing velocities (Tranter and Smith, 1968).

Coles et al (1977) modified a Miller sampler for determining the distribution of pelagic fish larvae in Llyn Tegid, North Wales by attaching a suction pump to the cod-end of the net. This arrangement allowed the contents of the net to be emptied continuously and filtered through a cheesecloth bag to retain the larvae. A scaffolding pole hinged to the bow of the boat supported the sampler and facilitated variation of sampling depth. Sampling time could easily be adjusted by altering the interval between changes of the cheescloth bag. Placement of the net ahead of the bow of the boat eliminated the turbulence associated with towing gear. An important advantage of this system was that a large number of small discrete samples could be taken without the necessity of retrieving the net (Coles et al, 1977). The major drawback of the method was the inability to accurately determine the volume of water sampled during each sampling interval.

3.2.5 Purse Seines

One of the most effective types of larval fish sampling gear, especially when net avoidance is a problem, is a miniature purse seine (Hunter et al, 1966). Large volumes of water may be sampled and the seine is easy to handle, although sampling can be time-consuming. Murphy and Clutter (1972) described a purse seine constructed of 333 m Nitex mesh for sampling anchovy larvae. The seine was successful in catching both large and small larvae. Coles (1981) sampled perch *(Perca fluviatilis)* larvae in July using a 36.5 m long by 6.6 m deep purse seine made of 3 mm mesh knotless netting. Offshore purse seine hauls captured larvae up to 18 mm total length until the middle of July, when beach seine hauls demonstrated that juvenile perch were present inshore.

A purse seine haul represents a feasible alternative to sampling with a high-speed plankton sampler or a tow net but is associated with three main disadvantages. Quantitative samples can not be obtained with this method, which involves the encircling of fish larvae rather than an active filtration process. Further, the method precludes economical sample replication and the attainment of high precision (Kjelson, 1977). In addition, initial purse seine net costs are high ($3,000-5,000).

4.0 SUMMARY AND CONCLUSIONS

A brief review of the spawning behaviour and early life history of four fish species (yellow perch, yellow pickerel, cisco and northern pike) common to the Atikokan area lakes revealed a marked dissimilarity in spatial and temporal distribution patterns during the larval period of these fish species. Therefore no single larval fish sampling technique was likely to be appropriate for the entire early developmental phase of any species. The identification of two principal lacustrine habitats of freshwater fish larvae permitted the functional separation of sampling methods into those which could be applied in nearshore locations in the vicinity of aquatic macrophytes (inshore methods) and those which were more suitable for catching larvae that had dispersed into the upper strata of the epilimnion (offshore methods).

Inshore methods encompass a wide spectrum of predominantly non-quantitative sampling gear, including modified minnow traps, fine mesh beach seines, portable pumps, Breder traps, drop nets, lift nets and push-nets. Offshore methods include conical plankton tow nets, high-speed plankton samplers, push-nets and purse seines. Channel nets may also be considered as an offshore sampling method since epilimnetic larvae may be transported through narrow lake channels by surface currents. The

TABLE 1

SUMMARY OF RESULTS OF LARVAL FISH SAMPLING METHOD EVALUATION

INSHORE METHODS*	ADVANTAGES	DISADVANTAGES
Illuminated Breder traps	Ideal in areas of dense aquatic vegetation; low cost; high portability; easy to operate.	Not quantitative
Short, fine mesh beach seines	May be operated by one person; portable; minimal cost.	Not quantitative; debris accumulation; tedious sorting process.
Push-nets	Quantitative; concentrate fish larvae; relatively low cost.	Generally cumbersome to handle or require special attachments or boats; risk of engine fouling; most types restricted in very shallow water; net clogging; possible net avoidance.
Minnow traps	Portable; easy to handle; low cost.	Not quantitative; dependent on wind-generated surface currents.
Portable pumps	Relative ease of handling; no current meter problems; regulation of sampling volume.	Long operating time necessary to obtain representative sample; clogging of pump intake; high cost.
Drop nets and lift nets	Instantaneous samples;	Limited portability; small sampling area; replicate samples uneconomical to obtain; tedious sorting process; semi-quantitative.
OFFSHORE METHODS*	**ADVANTAGES**	**DISADVANTAGES**
Push-nets	Samples collected outside of wake of boat; no wires or bridles preceding net; relatively portable; operable at various depths (some); good filtration efficiency; quantitative.	Net avoidance by older fish larvae.
Conical plankton tow nets	Commercially available in different sizes; relatively low cost; ease of handling; quantitative.	Turbulence created ahead of nets; net avoidance; sampling volume affected by propwash; long tows integrate larval fish from different areas.
High-speed plankton samplers	Reduce net avoidance; quantitative.	Limited to large inland lakes; extrusion of small larvae through mesh; physical damage to larvae.
Purse seines	Large volumes of water sampled; eliminates net avoidance.	Not quantitative; sample replication uneconomical and imprecise; high cost.
Channel net	Requires minimal handling; quantitative; relatively large amount of water sampled.	Restricted to lake channels; potential for clogging.

* Presented in descending order of effectiveness.

advantages and disadvantages of both inshore and offshore larval fish sampling methods are summarized in Table I.

Short fine-meshed (0.5 mm) beach seines and illuminated Breder traps represent the most effective gear types with which to sample larval fish in shallow, vegetated areas. Both apparatuses are portable, easy to use and relatively inexpensive (approximately $500). The most serious disadvantage of using seines or Breder traps is that only relative larval fish abundance can be estimated. Newly-hatched yellow perch and possibly cisco larvae may be captured by these techniques. However, newly-hatched yellow pickerel larvae are carried rapidly into open water where they are unavailable to inshore sampling methods. Pike larvae are exceedingly difficult to catch as they are less active, large larvae capable of substantial evasive movement.

Push-net systems should be used in epilimnetic waters to capture yellow perch, cisco and yellow pickerel larvae. If lake currents are evident, sampling for yellow pickerel larvae should be conducted in the epilimnetic portion of sheltered bays.

ACKNOWLEDGEMENTS

O.B. Turczyn assisted in the collection and initial compilation of data.

Approved:

A. Vanoth
for

D. Harrison
Manager
Chemical Research Dept

WEC:njm

Submitted:

Wayne E. Carey

W.E. Carey
Biologist
Biological Research Section

REFERENCES

ACRES Consulting Servies Limited, 1976. Marmion Lake Environmental Studies. Vol 2 Existing Conditions. 231 p.

Ahlstrom, E.H. 1954. Distribution and Abundance of Egg and Larval Populations of the Pacific Sardine. Fish. Bull. US. Fish Wildl. Serv. 56: 83-140.

Amundrud, J.R., D.J. Faber and A. Keast. 1974. Seasonal Succession of Free-Swimming Perciform Larvae in Lake Opinicon, Ontario. J. Fish. Res. Board Can. 31(10): 1661-5.

Bagenal, T.B. and W. Nellen. 1980. Sampling Eggs, Larvae and Juvenile Fish. p. 13-36. In: T. Backiel and R.L. Welcomme (eds), Guidelines for Sampling Fish in Inland Waters. EIFAC Tech. Pap. (33): 176 p.

Bowles, R.R. and J.V. Merriner. 1978. Evaluation of Ichthyoplankton Sampling Gear Used in Power Plant Entrainment Studies. p 33-43. In: L.D. Jensen (ed), Fourth National Workshop on Entrainment and Impingement. Ecological Analysts, Inc., Melvile, NY. 424 p.

Breder, C.M. 1960. Design for a Fry Trap. Zoologica 45: 55-9.

Bridger, J.P. 1958. On Efficiency Tests Made with a Modified Gulf III High-Speed Tow Net. J. Cons. Perm. int. Explor. Mer 23(3): 357-65.

Cada, G.F. and J.M. Loar. 1982. Relative Effectiveness of Two Ichthyoplankton Sampling Techniques. Can. J. Fish. Aq. Sci. 39(6): 811-4.

Campana, S.E. 1982. Techniques for Conversion of a Beach Seine for Operation by One Person. Prog. Fish-Cult. 44(33): 152-3.

Clady, M.D. 1976a. Distribution and Abundance of Larval Ciscoes, *Coregonus artedii*, and Burbot, *Lota lota*, in Oneida Lake. J. Great Lakes Res. 2(2): 234-247.

Clady, M.D. 1976b. Influence of Temperature and Wind on the Survival of Early Stages of Yellow Perch, *Perca flavescens*. J. Fish. Res. Board Can. 33: 1887-1893.

Clarke, W.D. 1964. The Jet Net, a New High-Speed Plankton Sampler. J. Mar Res. 22(3): 284-7.

Clutter, R.I. and M. Anraku. 1968. Avoidance of Samplers. Unesco Monogr. Oceanogr. Methodol. (2): 57-76.

Coles, T.F. 1981. The Distribution of Perch, *Perca fluviatilis* L. Throughout Their First Year of Life in Llyn Tegid, North Wales. J. Fish Biol. 18: 15-30.

Coles, T.F., G.N. Swinney and J.W. Jones. 1977. A Technique for Determining the Distribution of Pelagic Fish Larvae. J. Fish Biol. 11: 151-159.

Cooper, C.L., W.C. Bartholomew, C.E. Herdendorf, J.M. Reutter and F.L. Snyder. 1981. Limnetic Larval Fish of the Maumee and Sandusky River Estuaries. J. Great Lakes Res. 7(1): 51-54.

Cooper, C.L. M.R. Heniken and C.E. Herdendorf. 1981. Limnetic Larval Fish in the Ohio Portion of the Western Basin of Lake Erie, 1975-1976. J. Great Lakes Re. 7(3): 326-329.

Derickson, W.K. and K.S. Price, Jr. 1973. The Fishes of the Shore Zone of Rehoboth and Indian River Bays, Delaware. Trans. Am. Fish. Soc. 102(3): 552-562.

Faber, D.J. 1967. Limnetic Larval Fish in Northern Wisconsin Lakes. J. Fish. Res. Board Can. 24(5): 927-937.

Faber, D.J. 1968. A Net for Catching Limnetic Fry. Trans. Amer. Fish. Soc. 97(1): 61-63.

Fish, M.P. 1932. Contributions to the Early Life Histories of Sixty-Two Species of Fish from Lake Erie and its Tributary Waters. Bull. US. Bur. Fish. 10, Vol 47: 293-398.

Franklin, D.R. and L.L. Smith, Jr. 1963. Early Life History of the Northern Pike, *Esox lucius* L., with Special Reference to the Factors Influencing the Numerical Strength of Year Classes. Trans. Amer. Fish. Soc. 92(2): 91-110.

Fraser, J.H. 1968. The History of Plankton Sampling. Unesco. Monogr. Oceanogr. Methodol. (2): 1-26.

Forney, J.L. 1971. Development of Dominant Year Classes in a Yellow Perch Population. Trans. Am. Fish. Soc. 100(4): 739-749.

Forney, J.L. 1975. Abundance of Larval Walleyes *(Stizostedion vitreum)* Estimated from the Catch in High-Speed Nets. EIFAC Tech. Pap. (23) Suppl. 1, Vol 2: 581-588.

Gale, W.F. and H.W. Mohr, Jr. 1978. Larval Fish Drift in a Large River with a Comparison of Sampling Methods. Tran. Amer. Fish. Soc. 107(1): 46-55.

Hansen, M.J. and D.H. Wahl. 1981. Selection of Small *Daphnia pulex* by Yellow Perch Fry in Oneida Lake, New York. Tran. Amer. Fish. Soc. 110: 64-71.

Herke, W.H. 1969. A Boat-Mounted Surface Push-Trawl for Sampling Juveniles in Tidal Marshes. Prog. Fish-Cult. 31: 177-179.

Hodson, R.G., C.R. Bennett and R.J. Monroe. 1981. Ichthyoplankton Samplers for Simultaneous Replicate Samples at Surface and Bottom. Estuaries 4(3): 176-184.

Holland, L.E. and G.S. Libey. 1981. Boat Attachments for Ichthyoplankton Studies in Small Impoundments. Prog. Fish-Cult. 43(1): 50-51.

Houde, E.D. 1969. Distribution of Larval Walleyes and Yellow Perch in a Bay of Oneida Lake and its Relation to Water Currents and Zooplankton. NY Fish and Game J. 16(2): 184-205.

Houde, E.D. and J.L. Forney. 1970. Effects of Water Currents on Distribution of Walleye Larvae in Oneida Lake, New York. J. Fish. Res. Board Can. 27: 445-456.

Hunter, J.R., D.C. Aasted and C.T. Mitchell. 1966. Design and Use of a Miniature Purse Seine. Prog. Fish-Cult. 28: 56-59.

John, K.R. and A.D. Hasler. 1956. Observations on Some Factors Affecting the Hatching of Eggs and the Survival of Young Shallow-water Cisco, *Leucichthys artedii* le Seur, in Lake Mendota, Wisconsin. Limnol. Oceanogr. 1(3): 176-194.

Johnson, M.G., J.H. Leach, C.K. Minns and C.H. Olver. 1977. Limnological Characteristics of Ontario Lakes in Relation to Associations of Walleye *(Stizostedion vitreum vitreum)*, Northern Pike *(Esox lucius)*, Lake Trout *(Salvelinus namaycush)*, and Smallmouth Bass *(Micropterus dolomieui)*. J. Fish. Res. Board Can. 34: 1592-1601.

Kjelson, M.A. 1977. Estimating the Size of Juvenile Fish Populations in Southeastern Coastal-Plain Estuaries. p. 71-90. In: W. Van Winkle (ed) Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations. Pergamon Press, New York. 380 p.

Kushlan, J.A. 1974. Quantitative Sampling of Fish Populations in Shallow Freshwater Environments. Trans. Amer. Fish Soc. 103: 348-352.

Lam, C.N.H. 1977. Distribution and Abundance of the Early Developmental Phases of Alewife, *Alosa pseudoharengus* (Wilson) and Other Fishes in the Bay of Quinte. M.Sc. Thesis. University of Guelph Library, Guelph, Ontario.

Leithiser, R.M., K.F. Ehrlich and A.B. Thum. 1979. Comparison of a High Volume Pump and Conventional Plankton Nets for Collecting Fish Larvae Entrained in Power Plant Cooling Systems. J. Fish. Res. Board Can. 36: 81-84.

Lewis, R.M., W.F. Hettler, Jr., E.P.H. Wilkens and G.N. Johnson. 1970. A Channel Net for Catching Larval Fishes. Chesapeake Sci. 11: 196-197.

Miller, D. 1961. A Modification of the Small Hardy Plankton Sampler for Simultaneous High-Speed Plankton Hauls. Bull. Mar. Ecol. 5: 165-172.

Miller, J.M. 1973. A Quantitative Push-Net System for Transect Studies of Larval Fish and Macrozooplanton. Limnol. Oceanogr. 18: 175-178.

Mizera, J.J., C.L. Cooper and C.E. Herdendorf. 1981. Limnetic Larval Fish in the Nearshore Zone of the Western Basin of Lake Erie. J. Great Lakes Res 7(1): 62-64.

Murphy, G.I. and R.I. Clutter. 1972. Sampling Anchovy Larvae with a Plankton Purse Seine. Fish. Bull. 70: 789-798.

Nellen, W. and D. Schnack. 1975. Sampling Problems and Methods of Fish Eggs and Larvae Investigations with Special Reference to Inland Waters. EIFAC Tech. Pap. (23) Suppl. 1, Vol 2: 538-551.

Nelson, W.R. 1980. Ecology of Larval Fishes in Lake Oahe, South Dakota. US Fish and Wildl. Serv. Tech. Pap. 101: 1-18.

Nelson, W.R. and C.H. Walburg. 1977. Population Dynamics of Yellow Perch *(Perca flavescens)*, Sauger *(Stizostedion canadense)*, and Walleye *(S. vitreum vitreum)* in Four Main Stem Missouri River Reservoirs. J. Fish. Res. Board Can. 34(10): 1748-1763.

Noble, R.L. 1970. Evaluation of the Miller High-Speed Sampler for Sampling Yellow Perch and Walleye Fry. J. Fish. Res. Board Can 27: 1033-1044.

Noble, R.L. 1972a. Distribution of Walleye and Yellow Perch Fry in a Bay of Oneida Lake. NY Fish and Game J. 19(2): 168-177.

Noble, R.L. 1972b. Mortality Rates of Walleye Fry in a Bay of of Oneida Lake, New York. Trans. Amer. Fish. Soc. 101: 720-723.

Ontario Hydro Research Division Report No 78-192-K, 1978. Larval Fish Entrainment at Bruce GS 'A', 1977. T.G. Dunstall.

Ontario Hydro Research Division Report No 80-186-K, 1980. A Literature Review of Ichthyoplankton Sampling Devices and Procedures. T.G. Dunstall and L.P. King.

Ontario Hydro Research Division Report No 81-211-K, 1981. Ichthyoplankton Entrainment at Pickering GS 'A', 1975-77. T.G. Dunstall.

Pritchard, A.L. 1930. Spawning Habits and Fry of the Cisco *(Leucichthys artedi)* in Lake Ontario. Contrib. Can. Biol. Fish. Stud. Biol. Sta. Canada n.s. 6(9): 227-240.

Ruelle, R., W. Lorenzen and J. Oliver. 1977. Population Dynamics of Young-of-the-Year Fish in a Reservoir Receiving Heated Effluent. p. 46-67. In: W. Van Winkle (ed), Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations. Pergamon Press, New York. 380 p.

Scott, W.B. and E.J. Crossman, 1973. Freshwater Fishes of Canada. Bulletin 184, Fisheries Research Board of Canada, Ottawa, 966 p.

Spanovskaya, V.D. and V.A. Grigorash. 1977. Development and Food of Age O Eurasian Perch *(Perca fluviatilis)* in Reservoirs Near Moscow, USSR. J. Fish. Res. Board Can. 34(10): 1551-1558.

Stauffer, T.M. 1981. Collecting Gear for Lake Trout Eggs and Fry. Prog. Fish-Cult. 43(4): 186-193.

Stevens, D.E. 1977. Striped Bass *(Morone saxatilis)* Monitoring Techniques in the Sacramento-San Joaquin Estuary. p 91-109. In: W. Van Winkle (ed), Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations. Pergamon Press, New York. 380 p.

Tarplee, W.H., Jr., W.T. Bryson and R.G. Sherlinski. 1979. Portable Push-Net Apparatus for Sampling Ichthyoplankton. Prog. Fish-Cult. 41(4): 213-215.

Tranter, D.J. and P.E. Smith. 1968. Filtration Performance. Unesco Monogr. Oceanogr. Methodol. (2): 27-56.

Vannucci, M. 1968. Loss of Organisms Through the Meshes. Unesco Monogr. Oceanogr. Methodol. (2): 77-86.

Viljanen, M. and I.J. Holopainen. 1982. Population Density of Perch (*Perca fluviatilis L.*) at Egg, Larval and Adult Stages in the Dys-Oligotrophic Lake Suomunjarvi, Finland. Ann. Zool. Fennici 19: 39-46.

Wong, B. and F.J. Ward. 1972. Size Selection of *Daphnia pulicaria* by Yellow Perch (*Perca flavescens*) Fry in West Blue Lake, Manitoba. J. Fish. Res. Board Can. 29: 1761-1764.

POOR

QUALITY

ORIGINAL